A BRIEF SUMMARY OF THE GEOMORPHIC EVIDENCE FOR AN ACTIVE SURFACE HYDROLOGIC CYCLE IN MARS' PAST. T. J. Parker, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109 (timothy.j.parker@jpl.nasa.gov).

Origin and Maintenance of Martian Basins:

Because Mars is just over half the Earth's diameter (about 6800km), it does not exhibit global tectonism on a scale comparable to Earth and Venus. But because it is still a large body compared to Mercury and the moon, it has had an atmosphere and climate over the history of the solar system. This is why Mars has been able to retain surfaces produced both through volcanic and climatic processes that are intermediate in age between volcanic surfaces on the moon and Mercury and both types of surfaces on Venus and Earth. For the purposes of this discussion, this has important implications about the origins and evolution of topographic depressions that potentially may have contained lakes.

Tectonism is probably the most important process on Earth for producing closed depressions on the continents, and is clearly responsible for maintenance of the ocean basins through geologic time. This is probably also true for depressions in the highland terrains and lowland plains of Venus. On Mars, however, tectonism appears limited to relatively small amounts of regional extension, compression, and vertical motion largely due to crustal loading of the two major volcanic provinces - Tharsis and Elysium

Impact craters and large impact basins (including all or parts of the northern plains) are clearly more important sites for potential lake basins on Mars, though they were likely more important on Earth, and Venus as well, during the period of heavy meteorite bombardment throughout the solar system prior to 3.5Ga. Comparisons of the relative importance of other formative processes on Mars with those on Earth are less obvious, and some may be quite speculative, since our understanding of the early Martian environment is still rather limited.

Sedimentary Basins?:

The primary sources of influx into the northern plains are the circum-Chryse outflow channels, which include the largest channel systems on Mars, and several modest-size outflow channels and valley networks west and south of the Elysium volcanic complex. In addition, many valley networks terminate at the boundary between the southern highlands and northern plains, though the basin continues its gentle, regional gradient far beyond the mouths of these networks. This may suggest a common base level for these channels, or reworking of their distal reaches by a later highstand. The Chryse channels alone are large enough to have produced several large lakes, even a sea or ocean, within the northern plains over a very short span of time.

In the southern highlands, several basins on the order of several tens to a few hundred kilometers across, and parts of Valles Marineris have been found to contain remnants of former alluvial or lacustrine sedimentary deposits. Many of these basins were simply in the path of short-term catastrophic floods, and thus may not have contained lakes for very long. The thick Valles Marineris layered deposits occupy deep tectonic and collapse depressions in the Martian crust, and appear to have been fed by groundwater rather than overland flow. The deposits are on the order of kilometers thick and appear finely laminated (in high-resolution Viking Orbiter images), and so probably indicate the presence of lakes for long periods of time.

Many highland basins contain peculiar, hummocky deposits that have been interpreted as the eroded remnants of lake sediments. The largest highland basins, Argyre Planitia (800km interior diameter) and Hellas Planitia (1500km interior diameter) appear to contain massive accumulations of layered sediments that are now being exposed by eolian deflation. Those in Argyre may be on the order of hundreds of meters or more thick, whereas those in Hellas appear to have been as much as a few kilometers thick.

Channels as Sources for Ponded Water on Mars:

Outflow channels and valley networks on Mars are generally described as having originated from underground sources, by the catastrophic failure of a subterranean aquifer or by groundwater sapping, respectively. The best known outflow channels can, in fact, be traced back to a collapsed terrain source. Many valley networks have theater-like headward terminations which suggest flow of groundwater atop a permeability boundary at depth, similar to sapping valleys in the Colorado Plateau. Nirgal Vallis is an often-cited example of this type of network.

However, a number of outflow channels and valley networks do not exhibit subterranean sources. Two of the largest of these, Mawrth Vallis and Ma'adim Vallis, are problematic. Mawrth Vallis may indeed have had an underground source that has subsequently been buried by ejecta from the crater Trouvelot (at 26°N lat., 13° lon.). Ma'adim Vallis may not be a true outflow channel at all, as it exhibits many characteristics of large valley networks - such as numerous tributaries. If it is a "valley network" rather than an outflow channel, then it may be the largest on Mars - requiring an impressive groundwater system to carve it through sapping alone.

A number of relatively small-scale outflow channels and "stem" valley networks in the cratered uplands terminate headward at the surface, usually within moderate-size inter-crater plains regions (a few tens of thousands of square kilometers in area) that must have contained shallow lakes. In some cases, these lakes may have been fed by other channels further upslope, themselves fed through groundwater sapping or atmospheric precipitation, or both.

E.G., Mangala Valles:

Mangala Valles is a large outflow channel (about 850km long) in the eastern Memnonia region of Mars. The channel heads within a graben in Memnonia Fossae at 18.5°S latitude, 149.5° longitude. Mangala Valles is separated from Arsia Mons-derived volcanic plains by one of these ridges (from about 9°S to 20°S latitude, 147° longitude). The lower reaches of Mangala Valles begin where the channel crosses the remnant of another, less prominent northeast trending ridge at 9.5°S latitude, 151.5° longitude. South of this ridge the channel is a broad, relatively shallow system as much as 75km or more wide cut into a smooth plains surface. North of this ridge, Mangala Valles bifurcates into two large, incised channels, Mangala Valles tó the north and Labou Vallis to the northwest. Northern Mangala Valles is a complex system of separate anastomosing channels ranging from less than 10km to more than 40km in width. Labou Vallis is a much less complicated single channel, ranging from about 5km to 40km wide.

An alternative interpretation to the graben source of Mangala Valles suggests that this plains uniis comprised of sediments deposited in a temporary lake which formed upstream from the northeast-trending ridge for two reasons. (I) Headward erosion escarpments within the Hchp unit (from about 10°S to about 16.5°S latitude on the east side of Mangala) are reminiscent of knick-point or cataract development in a rapidly drained lake. Current scours upstream from craters at 10.5°S latitude, 151° longitude and at 15°S latitude, 148.5° longitude, and others also suggest flow of water over the Hchp surface, rather than derived from the subsurface at the edge of the unit. (II) Spillways from the Hchp unit north across the heavily cratered terrain appear to have developed in at least two places prior to breaching of the ridge.

In this proposed flood scenario, then, the "true" source of the Mangala flood is the obstructing ridge at 9.5°S latitude, 151.5° longitude, which acted as a natural earthen dam that failed catastrophically. This explains why the most intense scouring and bifurcation of the system occur in this vicinity and downstream, where the flood's erosive capability was greatest. To the south (headward direction), this scouring became progressively less intense as the lake drained. The apparent source of the channel, the graben in Memnonia Fossae, therefore represents the point at which the lake level had dropped so that scouring of the bed, and subsequently the flood, ceased.

Where did the lake come from? The smooth plains surface extends from 9.5°S to almost 40°S latitude in the western hemisphere geologic map (Scott and Tanaka, 1986). I have identified a narrow sinuous channel, over 500km long and up to 1km wide, that appears to have originated in the vicinity of the terminus of Arsia Mons-derived volcanics to the east. This channel begins near 35°S latitude, 141° longitude, flowed initially southwestward for about 300km, then turned north within the Hpl_3 unit, eventually fading at about 34°S latitude, 147° longitude. It becomes visible again at 31°S latitude, 149.5° longitude, and "flows" an additional 50km or so northward. The plains between these two reaches comprise an area of approximately 40,000km^2, and may consist, in part, of lake sediments. A third reach can just be detected at 38.5°S latitude, 150.5° longitude, flowing north approximately 100km to 27°S latitude, 152° longitude, where it finally fades into the plains. The total length of this channel appears to be greater than 1500km. I would place the southern limit of the proposed lake at or near this latitude. The area of this lake would have been on the order of 60,000km^2. Assuming an average depth of 10-100m yields a total volume of 600-6000km^3, a rather modest volume for a Martian flood channel.

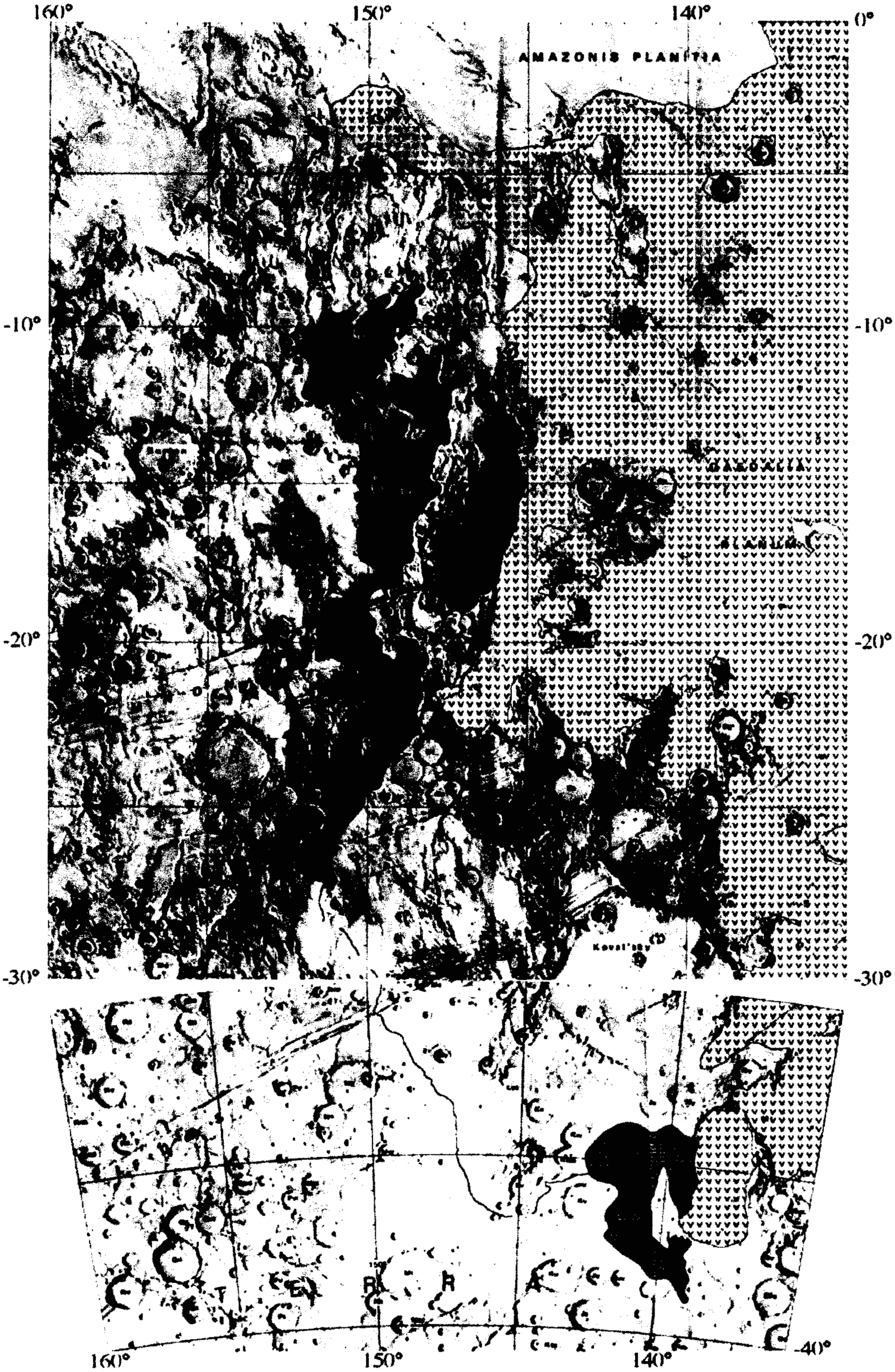

Figure 1: Shaded relief map of the Mangala Valles region of Mars. Dark gray wave pattern indicates locations of proposed source lakes. "V" pattern indicates extent of Arsia Mons Volcanic plains. Small, sinuous "source" channel is indicated by a thin black line connecting the southernmost lake with Mangala Valles.